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Lecture 14 - Introduction to experimental work

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Introduction to Experiments

Morten Kramer

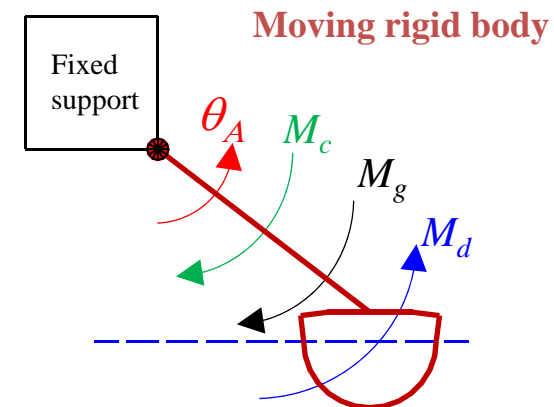
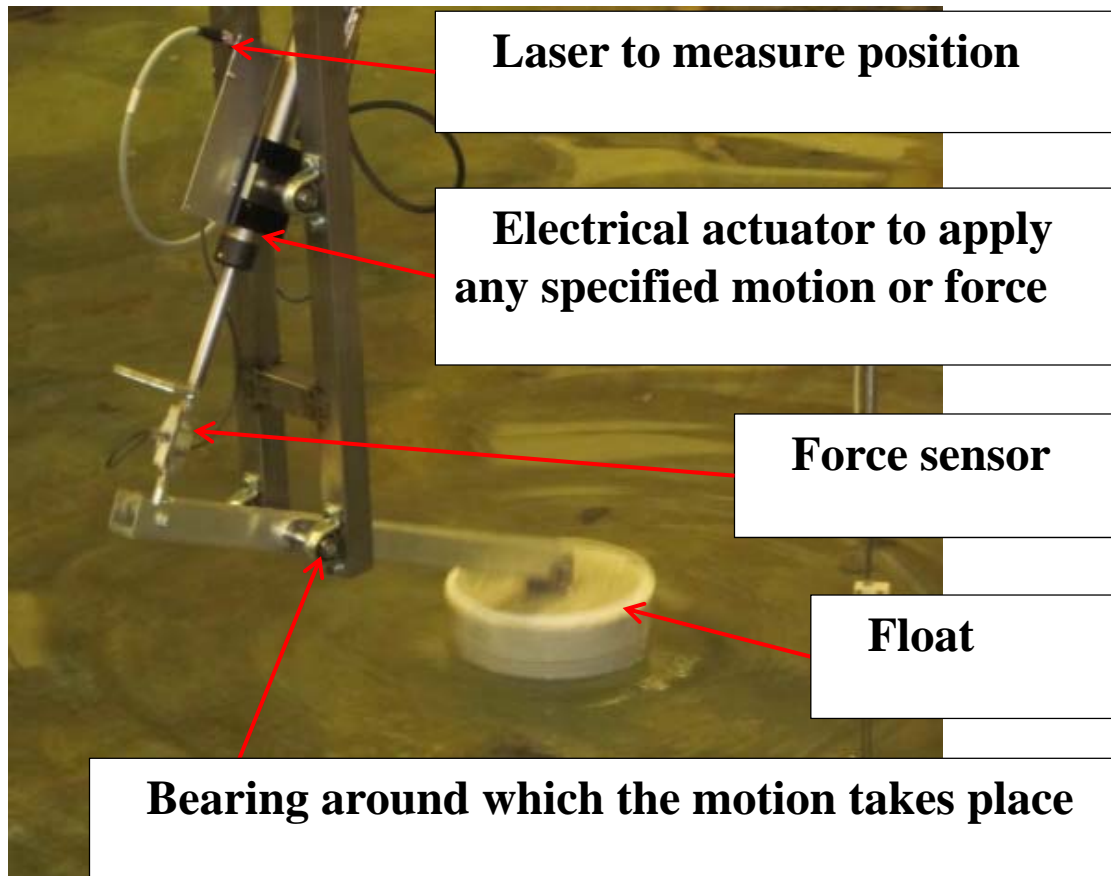
PhD course

”Numerical and experimental modelling and control of Wave Energy Converters”

Tuesday 1 September 2015

Location: Ecole Centrale Nantes, Nantes, France

Laboratory test set-up of pivoting absorber



Pivoting motions are described by rotations θ_A .

Newton's second law:

$$J\ddot{\theta}_A = M_d - M_g - M_c$$

J : Mass inertia moment of the moving body

M_d : Hydrodynamic moment
(from water pressure on hull)

M_g : Gravitational moment

M_c : Control moment from Power Take Off

Control sketch



Laptop

Simulink model. Model is compiled to C/C++ code and transferred to xPc before tests are executed.



PC with xPc

Online execution of control model and data acquisition. The control model specifies the target force or position based on measured inputs from the NI DAQ.



NI DAQ

Data logger with inputs and outputs. One output for the Linmot controller is the target force or position.



Linmot controller

Hardware controller. Takes care of achieving the specified target position or force using position feedback from actuator or force feedback from external force sensor.



Actuator

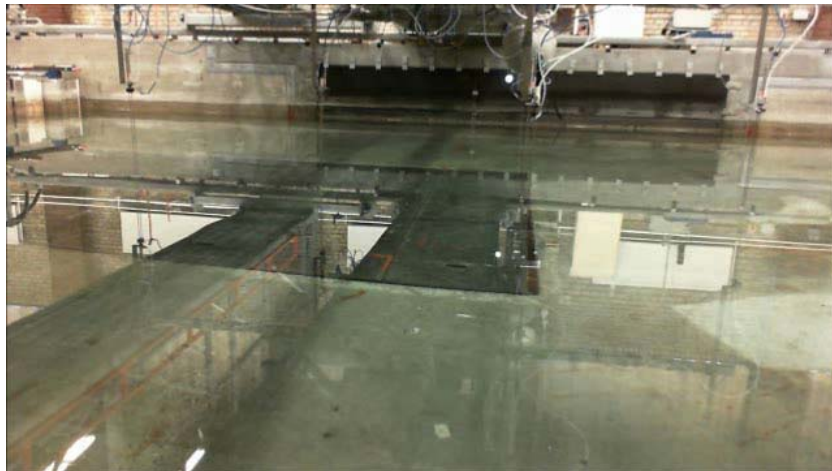
Linear motor (electrical cylinder). The linear motor consists of two parts: The fixed stator (tube) and the moveable slider (piston). An internal position encoder is included and used for position control.

Waves in basin

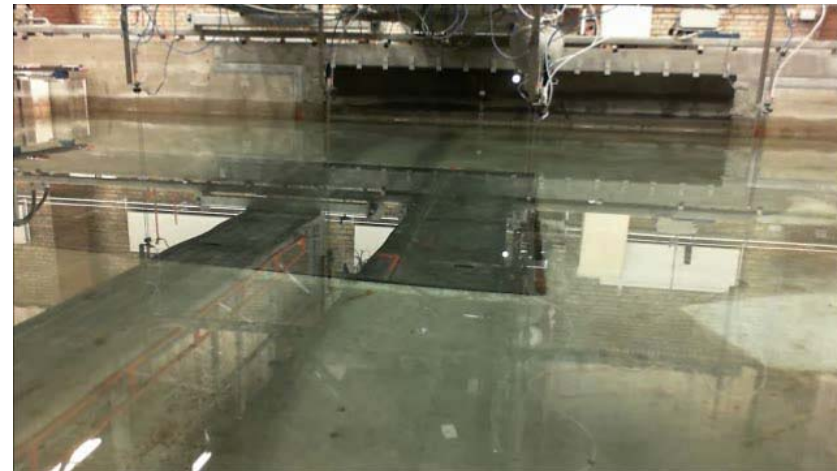
Waves are measured without the device in the basin.

Measured waves are considered as incoming waves (reflections from the beach and side walls are not taken into account).

Small wave



Large wave



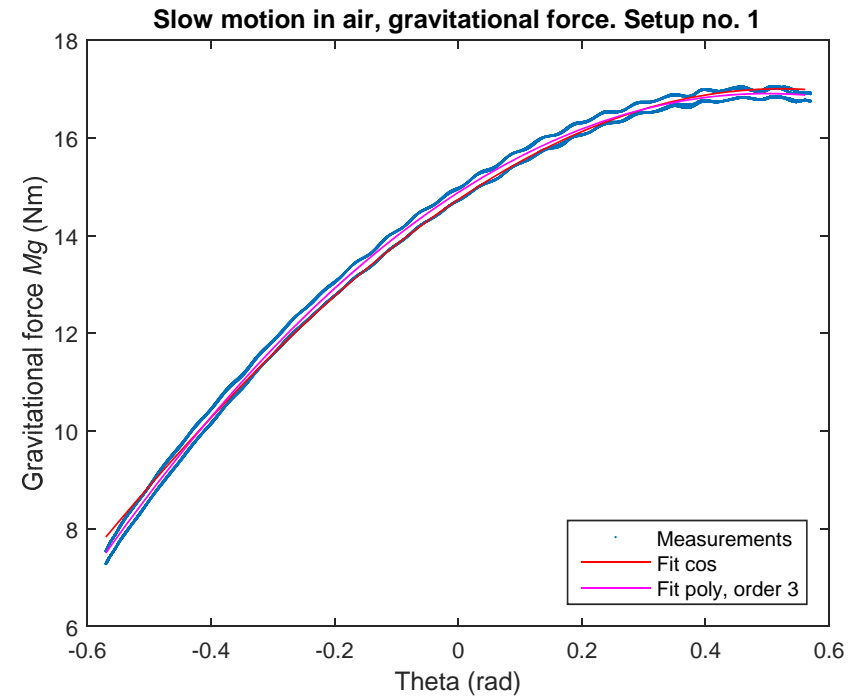
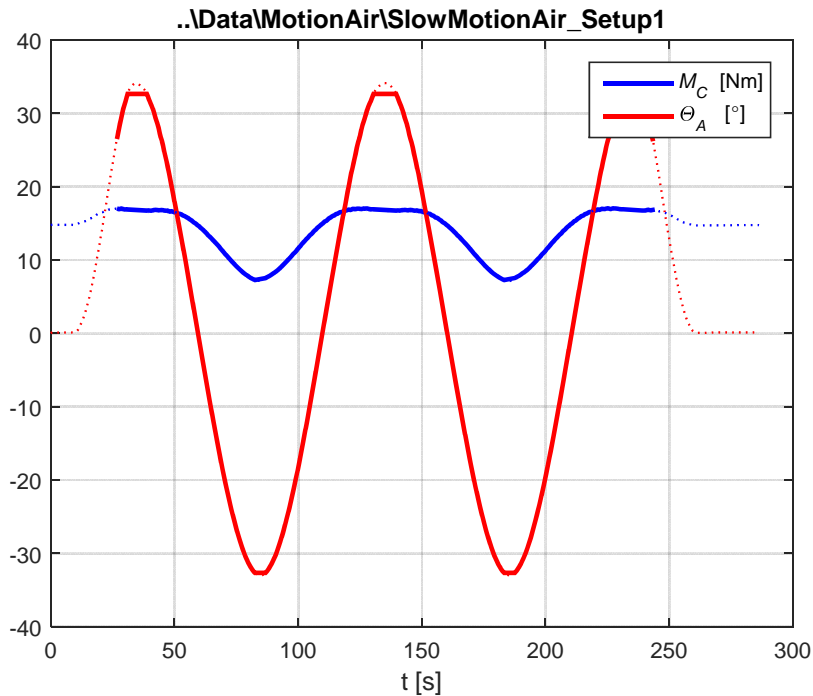
Moment due to gravity

$$J\ddot{\theta}_A = M_d - M_g - M_c$$

$$\Leftrightarrow 0 = 0 - M_g - M_c, \quad \ddot{\theta}_A \cong M_d \cong 0$$

$$\Leftrightarrow M_g = -M_c$$

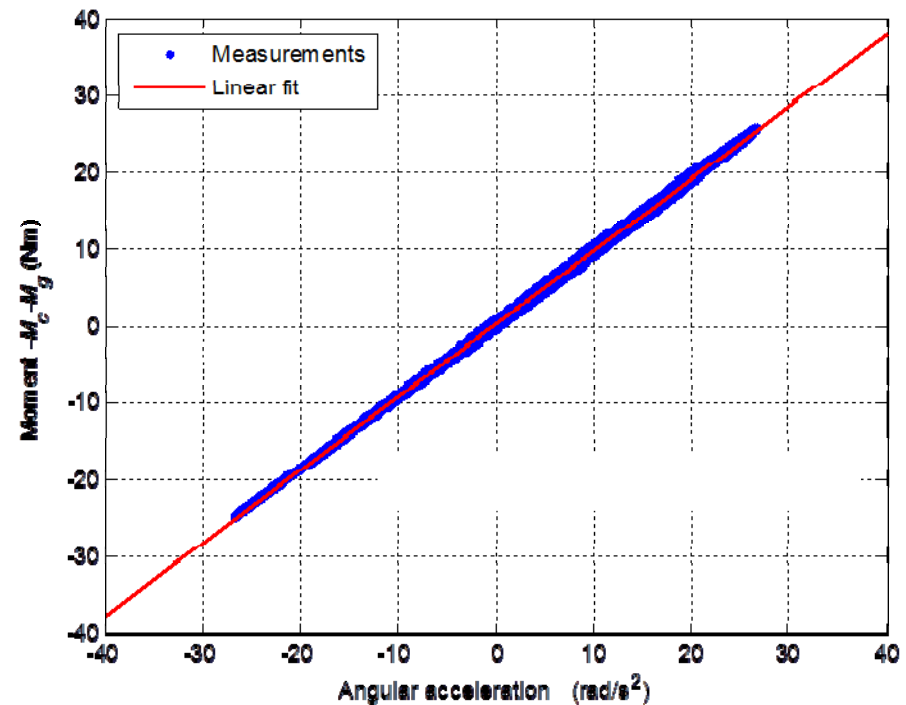
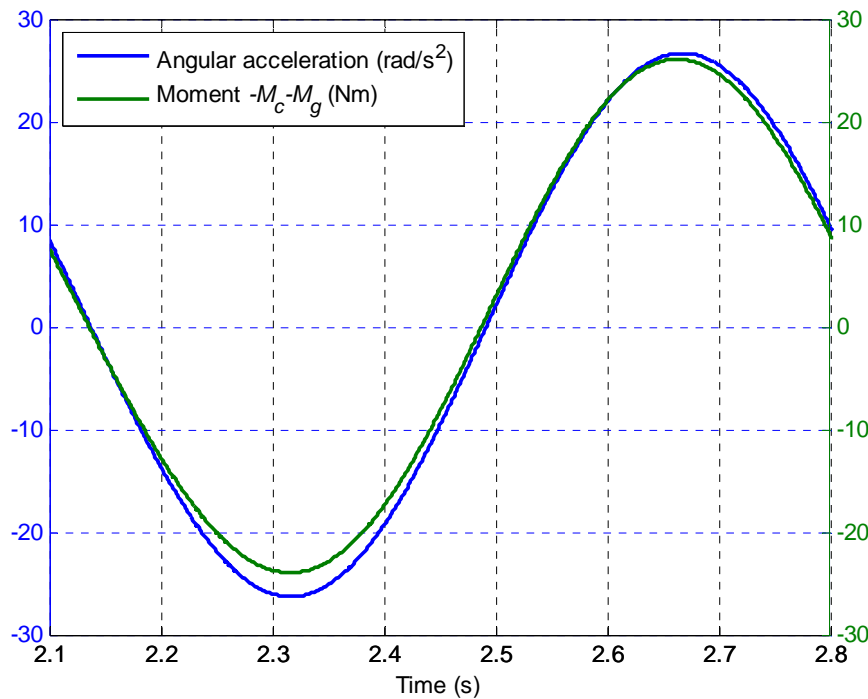
Slow motion in air with sinus



Mass inertia moment

Accelerating motion in air

$$\begin{aligned}
 J\ddot{\theta}_A &= M_d - M_g - M_c \\
 \Leftrightarrow J\ddot{\theta}_A &= 0 - M_g - M_c, & M_d &= 0 \\
 \Leftrightarrow -M_c - M_g &= J\ddot{\theta}_A
 \end{aligned}$$

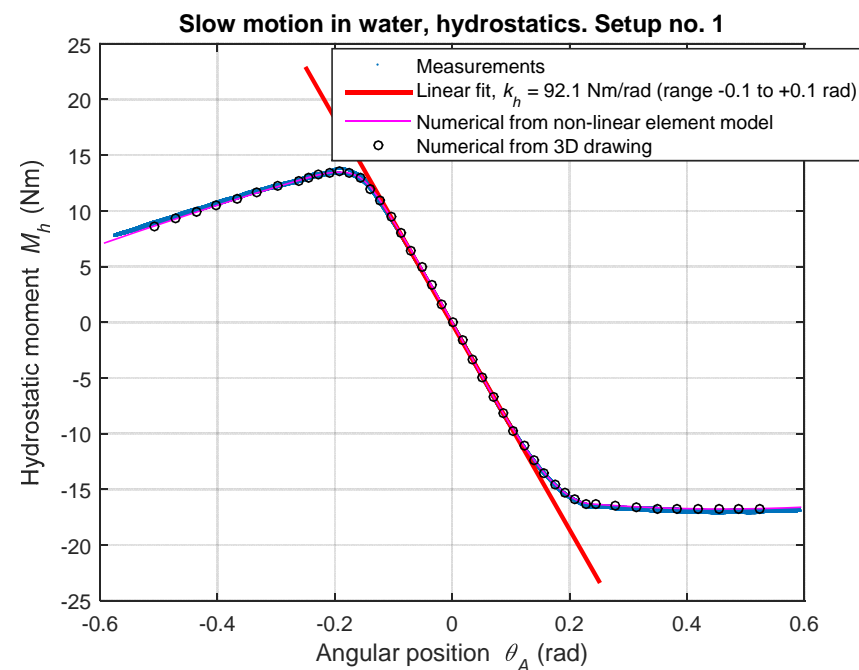
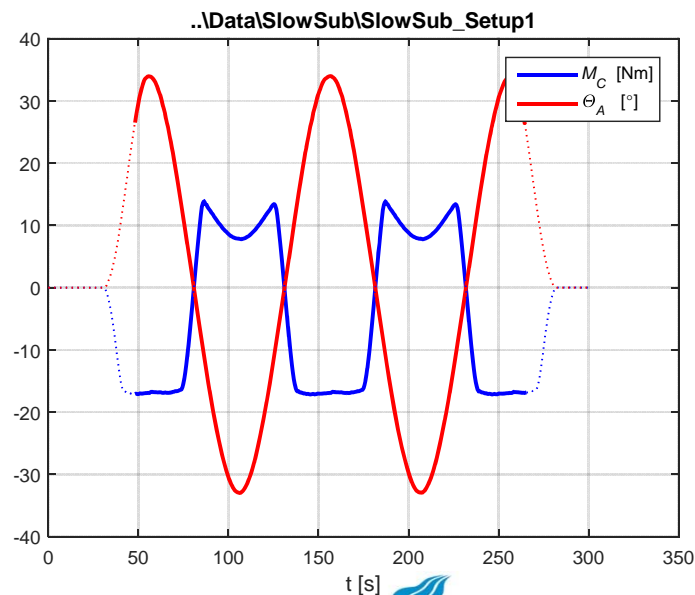
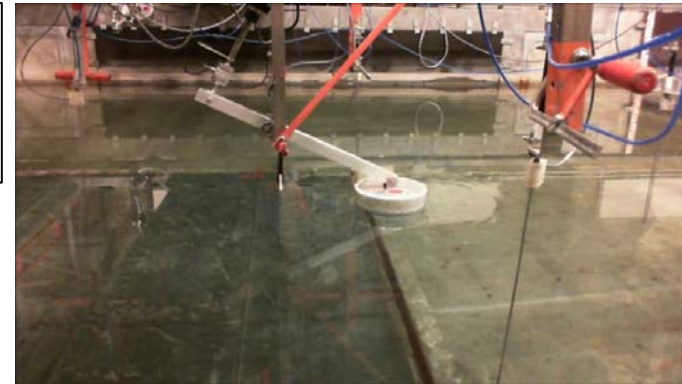


Hydrostatic stiffness

Slow sinusoidal motion in calm water

$$\begin{aligned}
 J\ddot{\theta}_A &= M_{hs} + M_r + M_e - M_c \\
 \Leftrightarrow 0 &= M_{hs} + 0 + 0 - M_c, \ddot{\theta}_A \cong \dot{\theta}_A \cong 0 \\
 \Leftrightarrow M_c &= M_{hs}
 \end{aligned}$$

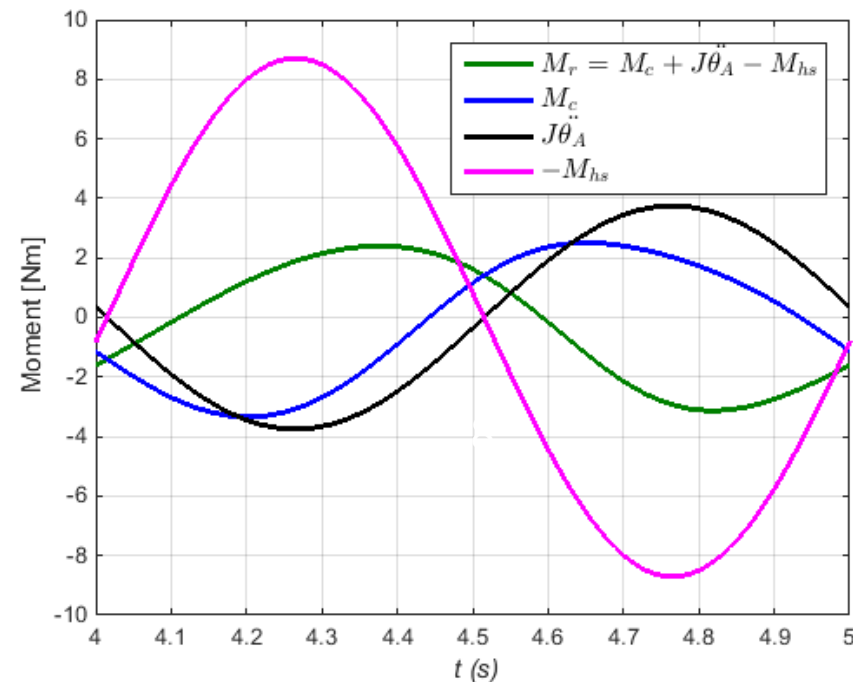
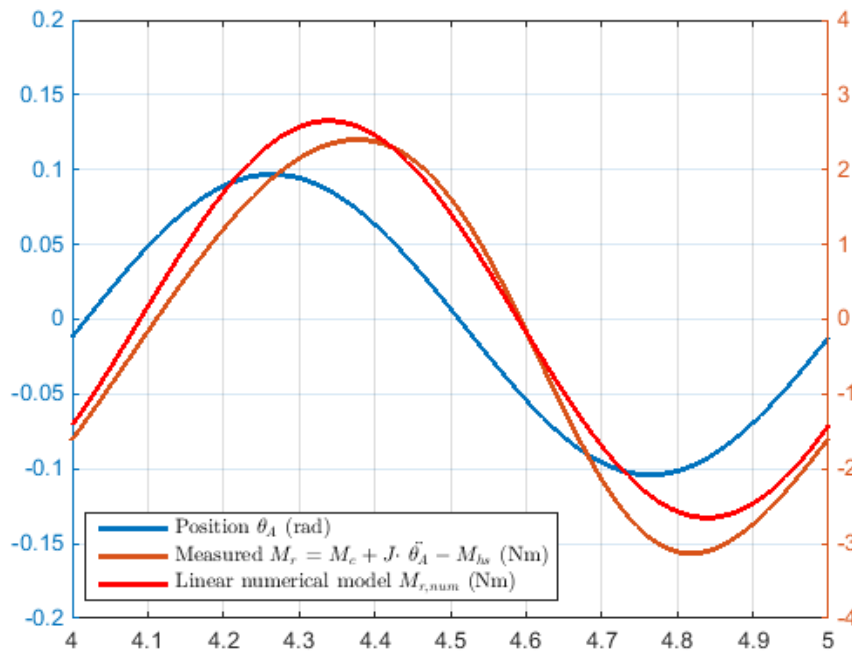
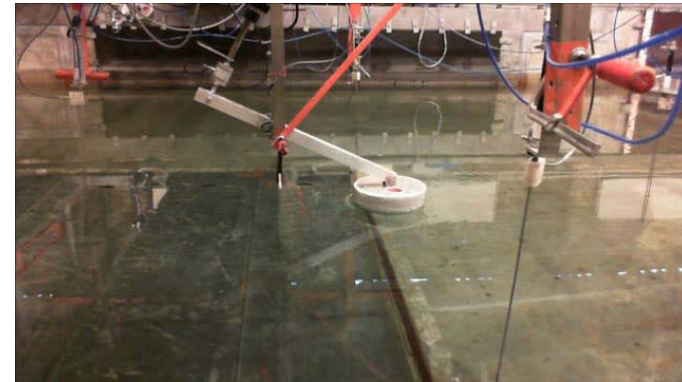
Hydrostatic moment: M_{hs}
 Radiation moment: M_r
 Wave excitation moment: M_e
 Control moment: M_c



Radiation force

Example figures with sinusoidal motion ($T = 1.0$ s, motion amplitude = 0.1 rad)

$$\begin{aligned} J\ddot{\theta}_A &= M_{hs} + M_r + M_e - M_c \\ \Leftrightarrow J\ddot{\theta}_A &= M_{hs} + M_r + 0 - M_c, & M_e &= 0 \\ \Leftrightarrow M_r &= M_c + J\ddot{\theta}_A - M_{hs} \end{aligned}$$



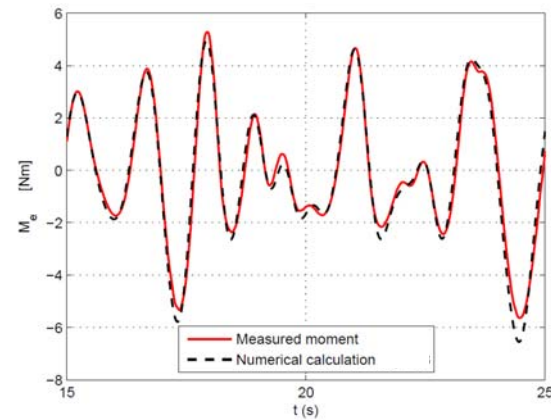
Wave excitation force

$$J\ddot{\theta}_A = M_{hs} + M_r + M_e - M_c$$

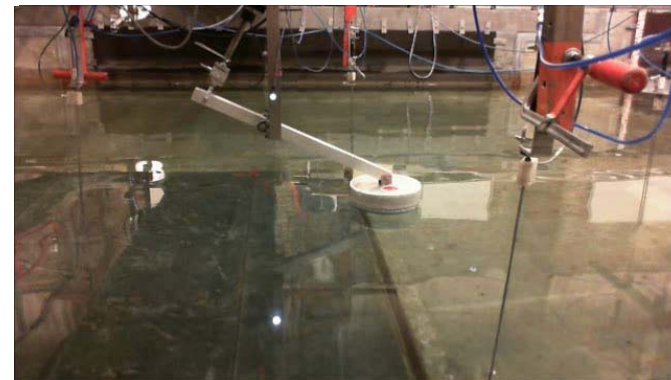
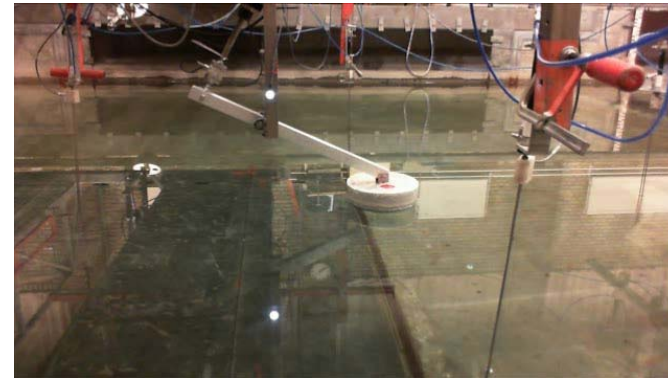
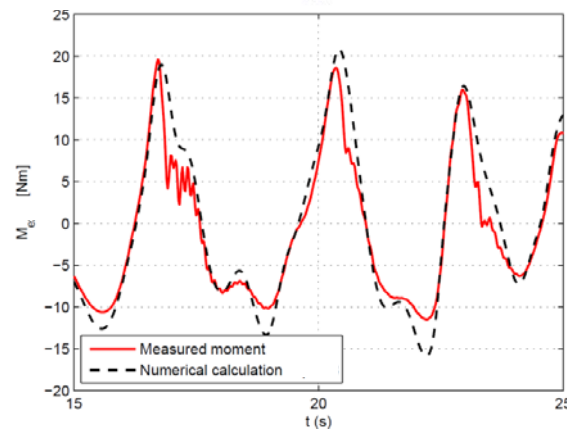
$$\Leftrightarrow 0 = 0 + 0 + M_e - M_c, \ddot{\theta}_A \cong \dot{\theta}_A \cong \theta_A \cong 0$$

$$\Leftrightarrow M_c = M_e$$

IRA4
 $H_{m0, WG4} = 0.081 \text{ m}, T_p = 2.0 \text{ s}$



IRB5
 $H_{m0, WG4} = 0.242 \text{ m}, T_p = 3.0 \text{ s}$



Float in operation

Example with sea-state IRB1 ($H_{m0, WG4} = 0.051$ m, $T_p = 1.0$ s)

Linear damping control $c_c = 4.0$ Nm/(rad/s), wave dir 0° , IRB1 ($H_{m0} = 0.051$ m, $T_p = 1.0$ s).

